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Assessment of plant diversity in the Surkhan-Sherabad Region, Uzbekistan by grid mapping

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Abstract: In floristic research, the grid mapping method is a crucial and highly effective tool for investigating the flora of specific regions. This methodology aids in the collection of comprehensive data, thereby promoting a thorough understanding of regional plant diversity. This paper presents findings from a grid mapping study conducted in the Surkhan-Sherabad botanical-geographic region (SShBGR), acknowledged as one of the major floristic areas in southwestern Uzbekistan. Using an expansive dataset of 14,317 records comprised of herbarium specimens and field diary entries collected from 1897 to 2023, we evaluated the stages and seasonal dynamics of data accumulation, species richness (SR), and collection density (CD) within 5 km×5 km grid cells. We further examined the taxonomic and life form composition of the region's flora. Our analysis revealed that the grid mapping phase (2021–2023) produced a significantly greater volume of specimens and taxonomic diversity compared with other periods (1897–1940, 1941–1993, and 1994–2020). Field research spanned 206 grid cells during 2021–2023, resulting in 11,883 samples, including 6469 herbarium specimens and 5414 field records. Overall, fieldwork covered 251 of the 253 grid cells within the SShBGR. Notably, the highest species diversity was documented in the B198 grid cell, recording 160 species. In terms of collection density, the E198 grid cell produced 475 samples. Overall, we identified 1053 species distributed across 439 genera and 78 families in the SShBGR. The flora of this region aligned significantly with the dominant families commonly found in the Holarctic, highlighting vital ecological connections. Among our findings, the Asteraceae family was the most polymorphic, with 147 species, followed by the continually stable and diverse Poaceae, Fabaceae, Brassicaceae, and Amaranthaceae. Besides, our analysis revealed a predominance of therophyte life forms, which constituted 52% (552 species) of the total flora. The findings underscore the necessity for continual data collection efforts to further enhance our understanding of the biodiversity in the SShBGR. The results of this study demonstrated that the application of grid-based mapping in floristic studies proves to be an effective tool for assessing biodiversity and identifying key taxonomic groups.

Keywords: grid mapping; species richness; collection density; taxonomy; dominant species; life form; therophyte; Central Asia

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1 Introduction

In the continued development of floristic research, the grid mapping method is pivotal (Yurtsev, 1987; Seregin, 2013). Grid mapping serves as an effective method for data storage and normalization, equipping researchers with the capacity to engage in theoretical analysis using statistical methodologies (Seregin, 2013). Grid maps are frequently used as the primary database for vegetation (Nakagoshi et al., 1998; Shcherbakov et al., 2021) and have predominantly been implemented in European countries for national biodiversity documentation and mapping (Shcherbakov et al., 2021). While floristic studies are often viewed as simply traditional, comprehending a region's flora is crucial for reducing the impact of human activities on biodiversity. Additionally, it is important for various modern botanical research endeavors, such as molecular studies on the taxonomy of key genera, which necessitates extensive floristic knowledge for accurate identification of the taxa under scrutiny (Wagensommer, 2023). Documenting the scientific aspects of a biogeographical area provides fundamental information that can steer conservation strategies and inform policies concerning biodiversity management (Haq et al., 2023). To understand the current status of biodiversity and to aid conservation efforts in a specific region, conducting floristic inventories and diversity evaluations is essential (Jayakumar et al., 2011). Such an inventory stems from the study and examination of a collection of herbarium specimens gathered in localities or stations within the area under investigation (Villaseñor and Meave, 2022).

Floristic research in Central Asia, which includes Uzbekistan, has a long-standing history. However, grid mapping-based floristic studies are relatively limited. Kodirov (2021) pioneered this field with his focus on the western branches of Zarafshan Range. This successful study set the foundation for future efforts such as implementing a state program titled "grid mapping of the flora of southwestern Hissar, Hissar-Darvaz, and Panj districts (part of Surkhandarya Province, Uzbekistan)" for the period of 2021–2024, sponsored by the Institute of Botany, Academy of Sciences of the Republic of Uzbekistan. This program developed a comprehensive grid system map of Surkhandarya Province, consisting of 884 grids each measuring 5 km×5 km, and led to extensive research across the majority of these grids. As of now, the only published results from this grid mapping initiative are focused on the endemic species of Surkhandarya Province (Tojibaev et al., 2022).

Surkhandarya Province is located in the southeastern part of Uzbekistan, comprising five botanical-geographic regions (BGRs), with the Surkhan-Sherabad botanical-geographic region (SShBGR) occupying the largest area (Tojibaev et al., 2016). Several floristic and geobotanical studies have been carried out in the SShBGR. Achilova (2021) explored the taxonomic composition of species within the SShBGR flora, analyzed habitat types, compared life forms, and mapped the species geographically. Achilova's study (2021) identified 802 species across 66 families and 362 genera, serving as the primary source of data on the SShBGR's flora to date. However, Achilova's study did not include analyses at the grid cell level or assessments based on different time periods. Furthermore, our extensive research, carried out under the aforementioned state program, suggests that this area's flora is more diverse than previously recorded. This highlights the need for a reevaluation of the taxonomic and life forms of the SShBGR flora.

It is necessary to examine the flora of specific regions, such as the SShBGR using grid mapping. We analyzed 14,317 data points collected from the SShBGR from 1897 to 2023. The primary objectives of this study are: (1) to analyze materials collected from the SShBGR for several decades and mark them on grid maps; (2) to scrutinize all collected materials at the grid level within the study area; (3) to identify the taxonomic composition of the SShBGR flora; and (4) to analyze the different life forms in the SShBGR flora. The results of this study will offer invaluable insights for future national documentation of the diversity of vascular plants in the SShBGR and enhance nature protection.

2 Materials and methods

2.1 Study area

In this study, we delineated the SShBGR territory based on the botanical-geographical regionalization scheme of Uzbekistan, developed by Tojibaev et al. (2016). The study area extends between 37.18°N–38.51°N and 66.52°E–68.15°E, covering 6234.1 km^2 with an elevation range of 268–802 m a.s.l. The region's total border length is 527 km, sharing boundaries with the Republic of Tajikistan and the Sangardak-Tupalang BGR, Surkhandarya Province to the north; Sangardak-Tupalang BGR, Boysun BGR, and Kuhitang BGR, Surkhandarya Province to the west; Afghanistan via the Amudarya River to the south; and Bobotog BGR, Surkhandarya Province to the east (Fig. 1). Approximately 65% of the SShBGR territory is utilized for agriculture and urban development, with the remaining 35% being deserts and hills. The Haudag Desert, known for its unique vegetation, is also located within this area. The region's average annual temperature ranges from 18.7°C to 19.8°C, with annual precipitation varying between 125 and 138 mm (Gelaro et al., 2017; Muñoz-Sabater et al., 2021). The study region belongs to the subtropical continental climate. Based on the region's natural geographical conditions and topography, Tojibaev et al. (2022) established a grid system, dividing the region into 5 km×5 km squares using geographical coordinates of 0.045° latitude and 0.057° longitude. The SShBGR encompasses the largest number of grid cells in Surkhandarya Province, totaling 253 grid cells (Fig. 1).

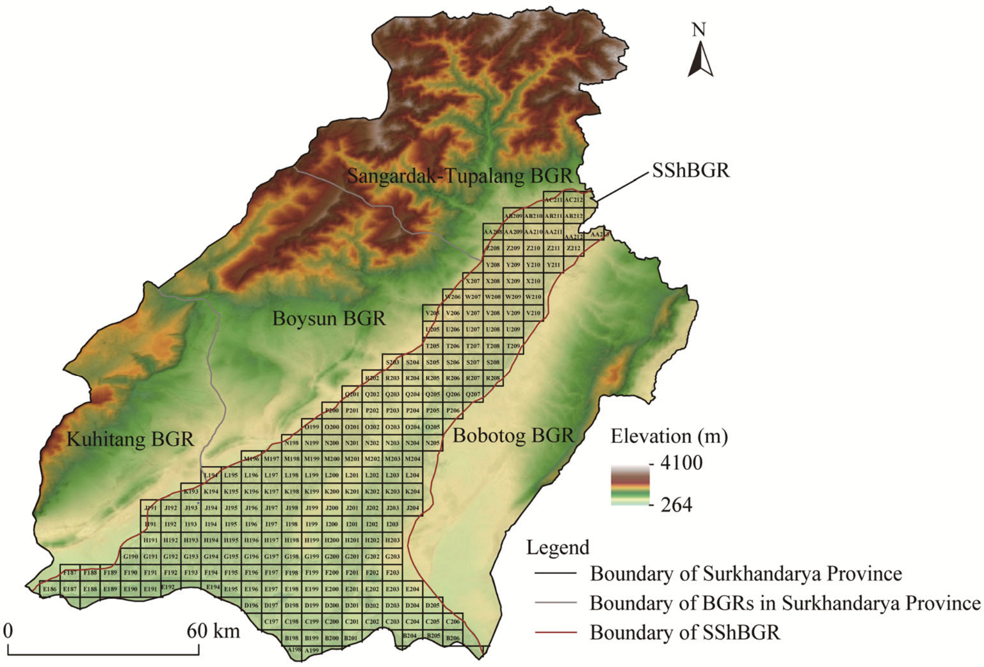

Fig. 1 Grid system established in the Surkhan-Sherabad botanical-geographic region (SShBGR). BGR, botanical-geographic region.

2.2 Implementing fieldwork

Before initiating fieldwork, we compiled all previously available species occurrence data, the majority of which were derived from herbarium records. These data were carefully reviewed, georeferenced, and standardized to ensure consistency and accuracy. We then integrated the compiled records into the SShBGR grid map, which has a resolution of 5 km×5 km. This process

allowed us to assess data completeness and identify grid cells with insufficient or missing species information, guiding the planning and prioritization of our field surveys. From 2021 to 2023, we conducted systematic fieldwork across the study area, with a particular focus on grid cells with missing species data. Surveys were carried out from February to September each year to maximize species detection across different seasons. Due to time constraints and resource limitations, we only conducted fieldwork in a total of 206 grid cells during this period, with each grid cell visited between one and four times, depending on its geographical location and accessibility. During field research, herbarium specimens were collected for rare species to ensure their proper identification and preservation. In contrast, species that occurred frequently within grid cells were recorded in a field diary without specimen collection. In total, we collected 11,883 species occurrence records, including 6469 herbarium specimens and 5414 field diary records. For each surveyed grid cell, detailed records were maintained for both herbarium specimens and species documented in the field diary. These records included essential information such as the collection date, precise location (GPS coordinates), habitat characteristics, elevation, and associated plant communities.

2.3 Calculation of species richness and collection density

Species richness (SR) was defined as the total number of species recorded within each 5 km×5 km grid cell across the study area. Collection density (CD), on the other hand, was measured as the total number of species occurrence records per grid cell (Wangchuk et al., 2014; Vollering et al., 2016). We used the two metrics to assess biodiversity patterns and sampling efforts within the study area. To ensure the accuracy and reliability of our data, we implemented a validation process before analysis. First, all species occurrence records were cross-checked against herbarium specimens and field notes to confirm correct species identification. Next, we verified georeferenced data using Google Earth software (Keyhole, Mountain View, USA) and ArcGIS v.10.8 software (Environmental Systems Research Institute Inc. (ESRI), Redlands, USA) to ensure that all location coordinates corresponded to the correct collection sites. Additionally, duplicate records were identified and removed to prevent data redundancy. Finally, statistical checks were performed to identify potential outliers or inconsistencies in species distribution patterns. Only validated occurrence records were included in the final analysis to minimize errors and enhance spatial accuracy.

2.4 Data sources and verification literature

In this study, we used a total of 14,317 species occurrence records from the SShBGR, stemming from surveys conducted from 1897 to 2023. These records comprised 8900 herbarium specimens and 5417 field diary entries. The majority of the herbarium specimens are preserved in the National Herbarium of Uzbekistan collection, with 8876 specimens. Additional data were obtained from the Moscow Digital Herbarium with 19 specimens and the herbarium of vascular plants of the Komarov Botanical Institute with 5 specimens. We collected voucher specimens for all species, processed them using standard herbarium techniques, and deposited them in the National Herbarium of Uzbekistan. We identified taxonomic based on several key literature, including Lipsky (1905), Popov (1916), Merkulovich (1936), and Nevsky (1937), the Flora of Uzbekistan (Kudryashev, 1941; Vvedensky, 1953, 1955, 1959, 1961, 1962), the Conspectus Florae Asiae Mediae (Kovalevskaya, 1968, 1971; Bondarenko and Nabiev, 1972; Pakhomova, 1974, 1976; Kamelin et al., 1981; Adylov, 1983, 1987; Nabiev, 1986; Adylov and Zuckerwanik, 1993), and the first six volumes of the new Flora of Uzbekistan (Sennikov, 2016, 2017, 2019, 2022, 2023a, b). Recent publications on specific plant groups were also consulted, including Tojibaev and Beshko (2015), Kljuykov et al. (2018), Tojibaev et al. (2020), Makhmudjanov et al. (2022), Sennikov et al. (2023), and Juramurodov et al. (2024). The nomenclature for each taxon followed the guidelines provided by Plants of the World Online (http://www.plantsofthe-worldonline.org) and the International Plant Names Index (www.ipni.org).

2.5 Georeferencing and decadal analysis of species records

To accurately document the collection sites of historical herbarium specimens, we performed a systematic georeferencing process. All historical herbarium specimens were georeferenced by extracting locality descriptions from specimen labels. These location descriptions were then converted into geographic coordinates using Google Earth software (Keyhole, Mountain View, California, USA). This method allowed for precise identification of collection sites by referencing satellite imagery, topographic features, and historical maps. During fieldwork, the geographic coordinates of plant collection sites were recorded *in situ* using a Garmin eTrex 10 GPS device (Garmin Ltd., Olathe, USA), ensuring real-time spatial accuracy. The recorded voucher data were organized using Microsoft Excel, where essential attributes were structured for further analysis. Subsequently, the georeferenced data were imported into ArcGIS v.10.8 software, where they were transformed into a grid map layer.

2.6 Floristic analysis

To determine the taxonomic composition of the SShBGR region, we analyzed existing species occurrence records collected from 1897 to 2023. We compiled a comprehensive list of dominant plant families based on the number of recorded species. To assess temporal changes in dominant families, we conducted separate analyses for four distinct time periods: period A (1897–1940; the initial research phase of Uzbekistan flora), period B (1941–1993; from the start of systematic study on Uzbekistan flora until Uzbekistan's independence), period C (1994–2020; spanning from Uzbekistan's independence until the commencement of grid-based research), and period D (2021–2023; the phase of grid-mapping research).

Given the geographical characteristics of the study area, we classified grid cells with fewer than 50 recorded species as having minimal floristic diversity and focused our analysis on those with higher species richness. Specifically, grid cells containing more than 50 species were designated as relatively floristically rich. To evaluate the role of dominant families in shaping the region's flora, we analyzed the occurrence rates of the ten most dominant families within these floristically rich grid cells.

To establish the optimal collection periods for species, we analyzed collection dates recorded in herbarium voucher data and field diary records, which were documented during key phenological stages, such as flowering and fruiting. This approach ensured that species were collected at the most suitable times for accurate identification and taxonomic verification.

In this study, we classified life forms of plant species based on Raunkiaer's system (Raunkiaer, 1934), including phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes. The life form of each species was determined through field observations, herbarium specimens, and relevant literature.

3 Results

3.1 Dynamics of data collection and their representation on the grid map of SShBGR

The highest values for SR and CD were observed during period D (Fig. 2). This period involved field research spanning 206 grid cells, yielding 11,883 samples, which comprised 6469 herbarium specimens and 5414 field records. In contrast, period A yielded 1265 samples from 187 grid cells, all of which were herbarium specimens. Period B resulted in 800 samples from 143 grid cells, including 797 herbarium specimens and 3 field records. Period C provided 362 samples from 37 grid cells, all of which were herbarium specimens. Additionally, the collection time for 7 samples remains unknown.

In this study, we analyzed the season of collection for 14,317 samples, representing 1053 species, gathered from the SShBGR territory between 1897 and 2023. Our findings indicated that May was the month that recorded the highest number of species collected, with a total of 4884 samples from 716 species. Also noteworthy is the significant amount of material collected in

Fig. 2 Distribution of species richness (SR) and collection density (CD) for data collected from the grid system in the SShBGR across different periods. (a), SR during 1897–1940; (b), CD during 1897–1940; (c), SR during 1941–1993; (d), CD during 1941–1993; (e), SR during 1994–2020; (f), CD during 1994–2020; (g), SR during 2021–2023; (h), CD during 2021–2023.

April (3081 samples from 560 species), March (3160 samples from 395 species), and June (1788 samples from 358 species) (Fig. 3). Due to the unknown collection dates, the collection months of 49 specimens from 36 species could not be determined.

Overall, field research was conducted and data were collected from 251 out of the 253 grid cells (except for U207 and N200), covering the SShBGR territory from 1897 to 2023 (Fig. 4). The analysis showed that the highest SR was found in the B198, which recorded 160 species. In terms of CD, the E198 had the highest count with 475 samples. The distribution of species across the grid cells unfolded as follows: 42 grid cells contained 1–10 species, 48 grid cells had 11–25 species, 79 grid cells included 26–49 species, 67 grid cells featured 50–100 species, and 15 grid cells recorded more than 100 species.

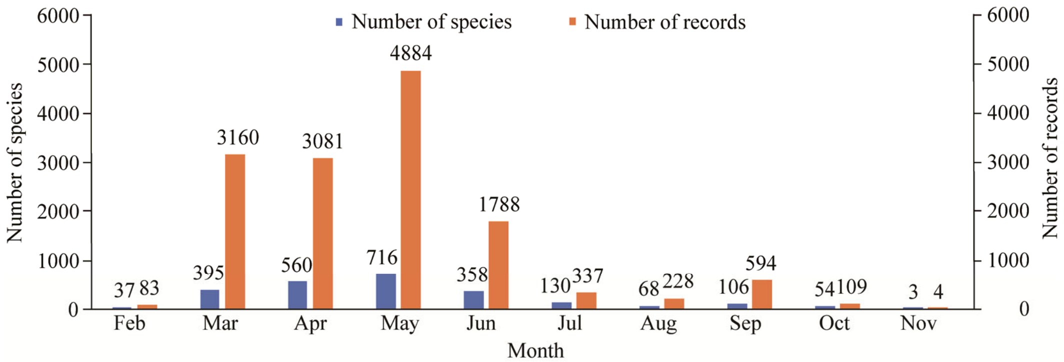

Fig. 3 Monthly dynamics of plant data collection from the SShBGR from 1897 to 2023

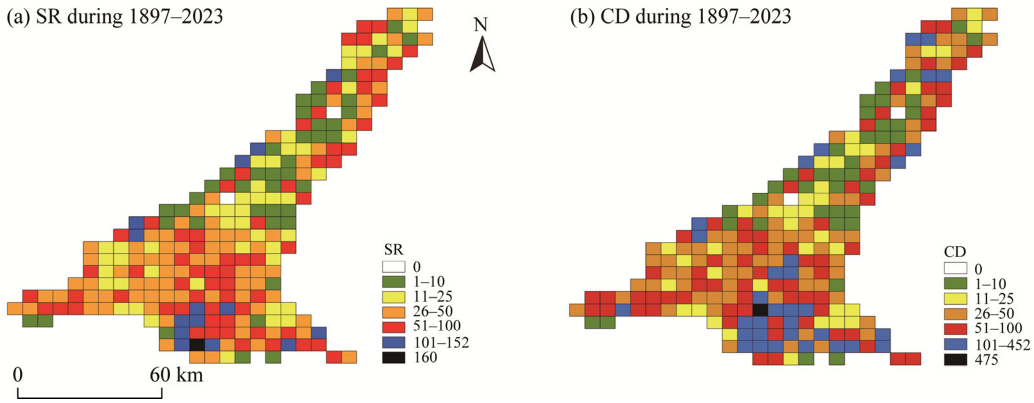

Fig. 4 Visualization of all species occurrence records collected from the SShBGR from 1897 to 2023. (a), SR during 1897–2023; (b), CD during 1897–2023.

3.2 Taxonomic analysis

The taxonomic analysis was conducted separately for each data collection period. Our findings indicated that the most species diversity was found in period D, which 803 species from 367 genera and 65 families were collected (Table 1). Conversely, period C offered the least species diversity, with 139 species from 105 genera and 38 families collected. Furthermore, we compiled a list of polymorphic families for the SShBGR, utilizing data from periods A, B, C, and D. Families such as Asteraceae, Poaceae, Fabaceae, Brassicaceae, and Amaranthaceae were identified as polymorphic across all four periods. Other families were also among the dominant families, though with some variations across different periods. For instance, Apiaceae was identified as polymorphic in all periods except period C, while Lamiaceae and Plantaginaceae displayed polymorphism in all periods except period D. Similarly, Boraginaceae was classified as

polymorphic in all periods except period C. Table 2 provides detailed information on the number of polymorphic families, genera, and species for each period.

Following a comprehensive review of herbarium specimens and records from field diaries collected from the SShBGR from 1897 to 2023, we cataloged data for 1053 species, spanning 78 families and 439 genera. Regrettably, 13 species' herbarium specimens lacked the requisite taxonomic characteristics for precise identification, resulting in their categorization as unspecified specimens at the species level. Based on these identified herbarium specimens and field diary record data, we generated a list of polymorphic families within the SShBGR. The Asteraceae, represented by 148 species across 58 genera, emerged as the most diverse family, followed by the Poaceae with 109 species across 53 genera, and Fabaceae, encompassing 97 species within 20 genera. Additionally, our analysis showed that only 1 species each from the Anacardiaceae, Balsaminaceae, Berberidaceae, Capparaceae, Colchicaceae, Crassulaceae, Datiscaceae, Elaeagnaceae, Elatinaceae, Eriocaulaceae, Hypericaceae, Ixioliriaceae, Linaceae, Mazaceae, Oleaceae, Oxalidaceae, Portulacaceae, Pteridaceae, Sapindaceae, Sphenocleaceae, Ulmaceae, Urticaceae, Verbenaceae, and Vitaceae were collected from the SShBGR territory. A complete list of all recorded families in the SShBGR is presented in Table 3.

Table 1 Number of plant families, genera, species, and records collected from the SShBGR across different periods

Period	Number of families	Number of genera	Number of species	Number of records
Period A (1897–1940)	54	244	428	1265
Period B (1941–1993)	49	181	299	800
Period C (1994–2020)	38	105	139	362
Period D (2021–2023)	65	367	803	11,883

Our analysis of the available data revealed that 82 out of 253 grid cells contained more than 50 species each. These grid cells included A207, B197–B199, B201, B203–B206, C197–C200, C202, C204, C206, D197–D200, E188–E190, E196–E201, F187, F190, F193, F198, F200–F202, G197, G199, G200, H191, H194, H198–H200, I197, I200–I202, J198, J204, K193, K194, K197, K198, L194, L195, L202, N205, O200, O204, P201, Q201, Q206, Q207, R202, R207, R208, T205, T209, U206, V210, W207, W209, X207, X209, X210, Y211, Z212, AA208, AA209, AB209, and AB210. Analysis of the 10 dominant plant families within the 82 grid cells identified as relatively floristically rich revealed consistent patterns in their distribution. The results showed that 5 families—Asteraceae, Poaceae, Fabaceae, Brassicaceae, and Amaranthaceae—were present in nearly all grid cells. Among these, Asteraceae, Poaceae, and Brassicaceae were found in every grid cell, while Fabaceae was absent only in L195, and Amaranthaceae was missing in AB209, G199, T205, W209, and X207. Conversely, species belonging to the Lamiaceae, Caryophyllaceae, Apiaceae, Boraginaceae, and Ranunculaceae families exhibited greater variability in their presence across the floristically rich grid cells. Specifically, these families were absent from 17, 16, 20, 16, and 34 grid cells, respectively.

3.3 Analysis of life forms

Our analysis of the 1053 species documented in the SShBGR revealed that the majority were therophytes, totaling 552 species or 52% of the total (Table 3; Fig. 5). The dominant families among the therophyte species were Asteraceae (85 species), Brassicaceae (73 species), and Poaceae (65 species). Additionally, we classified 303 species in the SShBGR flora as hemicryptophytes, with 43% belonging to the Asteraceae (48 species), Poaceae (43 species), and Fabaceae (38 species) families. We recognized 74 species with a cryptophyte life form, primarily within the Liliaceae (18 species), Amaryllidaceae (12 species), and Apiaceae (12 species) families. The SShBGR also comprised 62 species with phanerophyte life forms, representing 6% of the total species, with Polygonaceae (13 species), Tamaricaceae (11 species), and Amaranthaceae (7 species) as the most prominent families. Finally, we classified 62 species as

chamaephytes. Of these, 70% of them belong to the Asteraceae (13 species), Amaranthaceae (13 species), and Fabaceae (11 species) families.

Table 2 List of top-ten polymorphic families in the Surkhan-Sherabad botanical-geographic region (SShBGR) in each period

Period	Rank	Family	Number of genera	Number of species	Number of records
Period A (1897–1940)	1	Poaceae	35	48	190
	2	Asteraceae	25	45	137
	3	Fabaceae	13	42	148
	4	Brassicaceae	22	34	68
	5	Amaranthaceae	20	31	107
	6	Lamiaceae	13	18	37
	7	Apiaceae	11	18	52
	8	Boraginaceae	11	18	33
	9	Cyperaceae	7	18	44
	10	Plantaginaceae	6	12	31
Period B (1941–1993)	1	Poaceae	28	40	114
	2	Asteraceae	18	33	77
	3	Fabaceae	12	32	79
	4	Amaranthaceae	16	24	98
	5	Cyperaceae	5	13	42
	6	Lamiaceae	10	12	28
	7	Brassicaceae	10	11	14
	8	Apiaceae	9	11	20
	9	Plantaginaceae	3	7	10
	10	Boraginaceae	6	6	10
Period C (1994–2020)	1	Asteraceae	15	18	38
	2	Brassicaceae	11	12	46
	3	Poaceae	9	10	26
	4	Fabaceae	5	10	29
	5	Liliaceae	3	10	21
	6	Amaranthaceae	8	9	31
	7	Lamiaceae	8	8	13
	8	Caryophyllaceae	5	7	16
	9	Ranunculaceae	3	5	14
	10	Plantaginaceae	2	3	5
Period D (2021–2023)	1	Asteraceae	50	122	1567
	2	Poaceae	48	93	1847
	3	Fabaceae	19	73	1049
	4	Amaranthaceae	32	71	1025
	5	Brassicaceae	40	68	1432
	6	Caryophyllaceae	16	32	210
	7	Boraginaceae	14	29	396
	8	Apiaceae	23	28	181
	9	Polygonaceae	6	26	492
	10	Ranunculaceae	8	25	112

Table 3 Taxonomic and life forms of 14,317 records collected from the SShBGR from 1897 to 2023

No.	Family	Number of genera	Number of species	Number of life forms					Number of records
				T	H	Cr	Ch	P	
1	Asteraceae	58	147	85	48	1	13	-	1819
2	Poaceae	53	109	65	43	1	-	-	2178
3	Fabaceae	20	96	44	38	-	11	3	1305
4	Brassicaceae	45	80	73	7	-	-	-	1561
5	Amaranthaceae	33	79	59	-	-	13	7	1261
6	Lamiaceae	20	42	10	21	-	10	1	352
7	Caryophyllaceae	17	40	29	11	-	-	-	251
8	Apiaceae	29	39	16	11	12	-	-	255
9	Boraginaceae	16	39	27	12	-	-	-	439
10	Polygonaceae	7	28	9	6	-	-	13	567
11	Ranunculaceae	8	28	15	12	-	-	1	158
12	Cyperaceae	9	26	9	17	-	-	-	306
13	Plantaginaceae	7	25	14	11	-	-	-	502
14	Liliaceae	3	18	-	-	18	-	-	67
15	Euphorbiaceae	2	14	13	1	-	-	-	127
16	Rubiaceae	6	14	9	3	-	2	-	76
17	Convolvulaceae	4	13	3	7	-	3	-	340
18	Tamaricaceae	3	13	-	-	-	2	11	333
19	Amaryllidaceae	1	12	-	-	12	-	-	59
20	Caprifoliaceae	4	12	10	2	-	-	-	64
21	Malvaceae	5	12	6	6	-	-	-	225
22	Rosaceae	7	10	-	5	-	-	5	31
23	Papaveraceae	5	9	9	-	-	-	-	295
24	Geraniaceae	2	9	8	1	-	-	-	266
25	Solanaceae	4	9	5	-	-	1	3	113
26	Zygophyllaceae	2	7	2	2	-	3	-	233
27	Iridaceae	1	6	-	-	6	-	-	55
28	Juncaceae	1	6	-	6	-	-	-	15
29	Rutaceae	1	6	-	6	-	-	-	74
30	Typhaceae	1	6	-	-	6	-	-	74
31	Asparagaceae	4	5	-	-	5	-	-	12
32	Ephedraceae	1	5	-	-	-	-	5	38
33	Lythraceae	3	5	4	1	-	-	-	22
34	Orobanchaceae	2	5	-	5	-	-	-	19
35	Salicaceae	2	5	-	-	-	-	5	39
36	Scrophulariaceae	2	5	2	3	-	-	-	39
37	Plumbaginaceae	2	3	2	1	-	-	-	32
38	Apocynaceae	2	3	-	3	-	-	-	71
39	Araceae	2	3	-	-	3	-	-	41
40	Asphodelaceae	1	3	-	-	3	-	-	4
41	Cleomaceae	1	3	3	-	-	-	-	6

To be continued

Continued

No.	Family	Number of genera	Number of species	Number of life forms					Number of records
				T	H	Cr	Ch	P	
42	Frankeniaceae	1	3	1	-	-	2	-	10
43	Onagraceae	2	3	1	2	-	-	-	6
44	Orchidaceae	3	3	-	-	3	-	-	6
45	Primulaceae	1	3	3	-	-	-	-	34
46	Crassulaceae	1	1	1	-	-	-	-	1
47	Cynomoriaceae	1	2	2	-	-	-	-	5
48	Equisetaceae	1	2	-	-	2	-	-	34
49	Gentianaceae	2	2	1	1	-	-	-	22
50	Moraceae	1	2	-	-	-	-	2	23
51	Nitrariaceae	2	2	1	1	-	-	-	90
52	Phyllanthaceae	1	2	-	-	-	2	-	4
53	Potamogetonaceae	1	2	-	2	-	-	-	4
54	Resedaceae	1	2	2	-	-	-	-	5
55	Thymelaeaceae	2	2	2	-	-	-	-	15
56	Anacardiaceae	1	1	-	-	-	-	1	3
57	Balsaminaceae	1	1	1	-	-	-	-	4
58	Berberidaceae	1	1	-	1	-	-	-	2
59	Capparaceae	1	1	-	1	-	-	-	47
60	Colchicaceae	1	1	-	-	1	-	-	47
61	Datiscaceae	1	1	-	1	-	-	-	1
62	Elaeagnaceae	1	1	-	-	-	-	1	38
63	Elatinaceae	1	1	1	-	-	-	-	2
64	Eriocaulaceae	1	1	1	-	-	-	-	1
65	Hypericaceae	1	1	-	1	-	-	-	4
66	Ixioliriaceae	1	1	-	-	1	-	-	50
67	Linaceae	1	1	-	1	-	-	-	4
68	Mazaceae	1	1	-	1	-	-	-	30
69	Oleaceae	1	1	-	-	-	-	1	1
70	Oxalidaceae	1	1	1	-	-	-	-	20
71	Portulacaceae	1	1	1	-	-	-	-	53
72	Pteridaceae	1	1	-	1	-	-	-	1
73	Sapindaceae	1	1	-	-	-	-	1	2
74	Sphenocleaceae	1	1	1	-	-	-	-	5
75	Ulmaceae	1	1	-	-	-	-	1	7
76	Urticaceae	1	1	1	-	-	-	-	1
77	Verbenaceae	1	1	-	1	-	-	-	10
78	Vitaceae	1	1	1	-	-	-	1	1
Total		439	1053	552	303	74	62	62	14,317

Note: T, therophyte; H, hemicryptophyte; Cr, cryptophyte; Ch, chamaephyte; P, phanerophyte. "-" indicates no value.

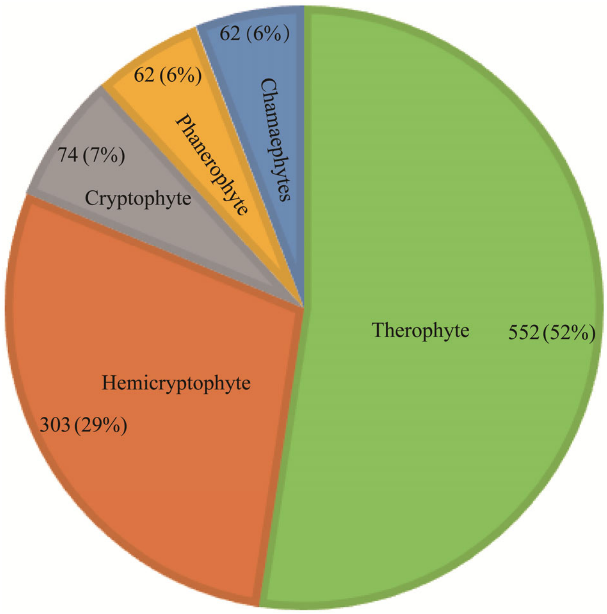

Fig. 5 Number and proportion of life form of the flora in the SShBGR

4 Discussion

Research involving grid mapping allows for the collection of a substantial amount of data within a short timeframe (Kiselyova et al., 2017; Seregin, 2021; Shcherbakov et al., 2021; Jogan et al., 2022; Sengeløv et al., 2025). The data obtained from the SShBGR territory over various periods reemphasizes the importance of systematic floristic research. Notably, the volume of collected data, including species occurrence records and their taxonomic diversity, was significantly higher during period D (2021–2023) compared with previous periods. This increase underscores the effectiveness of grid mapping in enhancing floristic studies and improving the accuracy of biodiversity assessments.

We knew that most herbarium specimens collected or recorded during field research focused on plants that have entered the phenological stage (Panchen et al., 2019). Our study's results showed that most plant species in the SShBGR flora were collected during March–May (Fig. 3).

As stated above, the SShBGR territory comprises 253 grid cells, with field studies conducted in 251 of them. An analysis of the gathered data revealed that less than 50 species occurrence records were collected from a total of 169 grid cells (68% of the total grids). The diminished number of specimens gathered from these grid cells can be attributed to various factors. The primary and most significant reason is the insufficient and untimely (out of season) field research conducted in these grid cells. Furthermore, many of grid cells reside in urbanized and agricultural areas, which may have limited field research opportunities.

The dominant families identified in the SShBGR by this study, namely Asteraceae, Poaceae, Fabaceae, and Brassicaceae, also ranked as the top 4 species-rich families in the flora of neighboring regions, including Boysun BGR (Turginov, 2017), Surkhan State Reserve (Ibragimov, 2009), Taqopchigay BGR (Abduraimov, 2022), and Urgut BGR (Kodirov, 2021). These BGRs are adjacent to the SShBGR. However, the environmental conditions of the SShBGR differ somewhat from those of the neighboring mountainous regions. While the surrounding regions are predominantly mountainous, the SShBGR primarily consists of plains and low hills. Despite these differences in topography, the dominant plant families in the SShBGR were found to be similar to those in the adjacent regions. However, there were differences in the number of polymorphic families further down the list. Notably, 79 species from 33 genera of Amaranthaceae

were recorded in the SShBGR, making it the fifth among the most species-rich families. Despite this, Amaranthaceae was not included among the 10 taxonomically richest families in the aforementioned neighboring regions (Ibragimov, 2009; Turginov, 2017; Kodirov, 2021), except in Tarqopchigay BGR, where it was listed as the seventh (Abduraimov, 2022). Amaranthaceae species are recognized for their resilience to challenging environmental conditions such as nutrient-poor soils, water scarcity, and severe defoliation (Bhargava and Srivastava, 2020; Terletskaya et al., 2023). Esanov (2023) noted that Amaranthaceae family dominates the flora of southwestern Kyzylkum Region, consisting primarily of plains and desert areas. The significant polymorphism of Amaranthaceae family in the SShBGR can be attributed to the presence of the Haudag Desert, considered to be the largest desert in the southwestern part of Uzbekistan.

Although Ma et al. (2024) reported that Amaryllidaceae and Rosaceae were among the top 10 dominant families in Central Asia, they ranked as the nineteenth and twenty-second, respectively, in the SShBGR flora. Preliminary studies suggested that Amaryllidaceae species are more prevalent in mountainous regions (Meerow and Snijman, 1998; Tojibaev et al., 2018). Similarly, most Rosaceae species are well adapted to mountainous environments (Özçelik et al., 2012; Zou et al., 2019; Shaheen et al., 2023). This suggested that the lower representation of Amaryllidaceae and Rosaceae in the SShBGR flora may be attributed to their ecological adaptations. In general, the majority of the dominant families recorded in the SShBGR aligned with those discovered in the Holarctic (Khokhryakov, 2000) and Central Asia (Ma et al., 2024). The similarity between the dominant families in the SShBGR and those in the Holarctic can be attributed to biogeographical and ecological factors. In particular, historical floristic connections and dispersal patterns may play a crucial role. During past geological periods, especially the Pleistocene, climatic fluctuations facilitated the migration and survival of temperate flora across Eurasia, which may lead to the presence of similar dominant families in both regions (Takhtajan, 1986).

Data analysis from the SShBGR revealed that therophytes dominate, comprising 52% (552 species) of the resident plant species. The diversity and distribution of plant life forms are majorly regulated by habitat type and bioclimatic conditions. Notably, therophytes exhibit exceptional adaptability to lower elevations as well as semi-arid or desert climates (Gholami et al., 2023; Midolo et al., 2024; Souddi et al., 2024). The SShBGR territory, comprising plains, hills, and desert, substantially supports the prevalence of therophytes. Moreover, the therophyte life form is also common in the southwestern part of Kyzylkum Region, highlighting shared geographical characteristics with the SShBGR (Esanov, 2023). However, in contrast, the mountainous areas adjoining the SShBGR witnessed a greater predominance of hemicryptophyte life form (Ibragimov, 2009; Turginov, 2017; Kodirov, 2021). The dominance of hemicryptophytes in mountainous areas can be attributed to their broad ecological adaptability. The gradual increase in the proportion of hemicryptophytes from lowlands to the alpine areas reflects their ability to adapt to stressful ecological conditions (Noroozi et al., 2008; Shaheen et al., 2023).

While this study reaffirmed the effectiveness of grid mapping in examining vegetation diversity in the SShBGR, it acknowledged the assessment of the impact of environmental factors on the region's vegetation as a limitation. Furthermore, the absence of molecular data for many species impeded the evaluation of phylogenetic diversity in the region. Hence, we proposed investigating the influence of environmental factors on the SShBGR's plants and assessing its phylogenetic diversity as potential avenues for future research. We also georeferenced historical herbariums using Google Earth software. This method may cause the coordinates to deviate by 500 to 1000 km from the original collection locations of the species; however, we have made concerted efforts to accurately set these coordinates based on the species' ecology. Moreover, it is crucial to continue data collection on various grid cells, particularly those not thoroughly explored at the phenological stage of plants. By collecting more comprehensive data on these grid cells, the understanding of species diversity in the SShBGR can be deepened and the reliability of grid-level analyses can be enhanced.

5 Conclusions

This study employed grid-based mapping for the detailed analysis of the flora in the SShBGR. Our study utilized 14,317 species occurrence records, comprising herbarium specimens and field diary entries collected from 1897 to 2023. By dividing this species occurrence records into four distinct periods, we demonstrated the effectiveness of grid-based research in studied regional flora. Our taxonomic analysis revealed that the flora of the SShBGR is richer than previously documented, with a total of 1053 species belonging to 439 genera and 78 families. Our results highlighted how the region's unique geographic features contribute to the flora's taxonomic composition, including the prominence of the Amaranthaceae family and the predominance of therophyte life form. As one of the few studies applying grid mapping to Central Asia's flora, this study demonstrated the effectiveness of grid mapping for documenting botanical data of Surkhandarya Province, Uzbekistan from 2021 to 2023. While this study does not provide an exhaustive account of the SShBGR flora, it serves as a valuable reference for future botanical research and conservation planning.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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